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Effect of Integrated Weed Management Practices on Weed Growth and Productivity of Pigeonpea (*Cajanus cajan*)

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Abstract

Field experiments were conducted for three years (2009–2011) on a loamy sand soil to study the effect of integrated weed management practices on weed growth and productivity of pigeonpea. Two hand weedings [25 and 50 days after sowing (DAS)] and pendimethalin (0.45 or 0.75 kg ha^{-1}) in integrated with hand weeding (50 DAS) or directed spray of paraquat [0.48 kg ha^{-1} at 6 or 8 weeks after sowing (WAS)] on weeds between the crop rows using a hood resulted in higher weed control efficiency and grain yield. Uncontrolled weeds caused 14.6–123.8% reduction in pigeonpea grain yield in different years. All the treatments of herbicides viz. pendimethalin (0.45 or 0.75 kg ha^{-1}) as pre-emergence, paraquat (0.48 kg ha^{-1}) and imazethapyr (75 g ha^{-1}) as post-emergence, applied either alone or in integration significantly reduced dry weight of weeds at 80 DAS and at harvest compared to weedy check. Application of pendimethalin @ 0.75 kg ha^{-1} followed by hand weeding (50 DAS) and two hand weedings (25+50 DAS) recorded the highest weed control efficiency. In the treatment where crop sown in rows 67.5 cm apart, interculture using a tractor provided effective weed control and high grain yield. Application of pendimethalin (0.45 or 0.75 kg ha^{-1}) as pre-emergence and tank mix application of imazethapyr (75 g ha^{-1})+quizalofop ethyl (50 g ha^{-1}) as post-emergence either alone or in integration with hand weeding at 50 DAS also reduced the dry weight of weeds and increased the grain yield.

Keywords: Imazethapyr, paraquat, pigeonpea, pendimethalin, weed control efficiency

1. Introduction

Pigeonpea [*Cajanus cajan* (L.) Millsp.], an important pulse crop of India, being a *kharif* season crop, is highly infested with grassy and broad leaved weeds. Timely weed control is essential for realization of yield potential of this crop (Suman et al., 2017). Due to wider row spacing and initial slow growth of pigeonpea, weeds pose a major problem to its productivity (Rajesh et al., 2015; Khazi et al., 2017). The crop canopy does not cover the inter row space during initial phase of growth and weeds compete with the crop plants for available moisture, nutrients and light and thus the crop suffers from early weed infestation. Therefore, it is necessary to keep the crop weed-free during the early growth period (4-6 weeks). In pigeonpea, weeds cause yield reduction up to 30-80% (Talnikar et al., 2008; Singh and Sekhon, 2013). Manual weeding and mechanical methods of weed control (Singh et al., 2010a) are quite effective, but they are costly and time consuming. Moreover, due to frequent rains it becomes difficult to do hand weeding (HW) at proper time. Therefore, there is a need to find out some other chemical and cultural weed management options which are efficient, less labour-intensive and less costly. The chemical weed control measures appear more convenient, less time consuming and less expensive. Only pre-emergence herbicides are available for weed control in pigeonpea. Application of pendimethalin as pre-emergence has been found promising in controlling weeds and improving grain yield (Reddy et al., 2007; Singh et al., 2010a, 2010b). Integrated use of pre- and post-emergence herbicides provides effective control of weeds and high grain yield of pigeonpea (Singh et al., 2016). However, pigeonpea is a long-duration crop and after about a month of pendimethalin application, weeds may pose a problem. Furthermore, weeds emerge in different flushes due to rainy season. Therefore, there was a need to study the effect of post-emergence herbicides and integrated weed management practices on growth of weeds as well as growth and productivity of pigeonpea.

2. Materials and Methods

2.1. *Site characterization*

Field experiments were conducted for three years during *kharif* (rainy) season from 2009 to 2011 at Punjab Agricultural University, Ludhiana, Punjab. The soil of the experimental site was loamy sand, having pH 7.8 and was low in organic carbon and available nitrogen and medium in available phosphorus and potash.

2.2. Crop husbandry

The crop was raised as per the details given in Table 1. After pre-sowing irrigation, at optimum soil moisture, the field was ploughed twice followed by planking. The crop was irrigated as per the need. The crop was raised with recommended package of practices (PAU, 2009).

Table 1: Treatments and crop husbandry details of experiments conducted from 2009 to 2011

Particulars	Experiment 1		Experiment 2		Experiment 3
Year	2009	2010	2010	2011	2011
Number of treatments	16	16	8	8	12
Replications	3	3	4	4	3
Plot size	7.0×2.5 m^2	7.0×2.5 m^2	9.0×4.0 m^2	10.0×4.0 m^2	7.0 m×2.5 m
Date of sowing	11.6.2009	8.6.2010	8.6.2010	8.6.2011	14.6.2011
Variety	PAU 881	PAU 881	PAU 881	PAU 881	PAU 881
Seed rate (kg ha^{-1})	15	15	15	15	15
Row spacing (cm)	50 cm	50 cm	50 cm and 67.5 cm	50 cm and 67.5 cm	50 cm
Date of harvest	3.11.2009	29.10.2010	29.10.2010	28.10.2011	28.10.2011

2.3. Treatments

Experiment 1 was conducted during 2009 and 2010 with sixteen treatments, as listed in Table 2, in randomized complete block design. Experiment 2 was conducted during 2010 and 2011 with eight treatments, as listed in Table 3, in factorial randomized complete block design. Experiment 3 was conducted during 2011 with twelve treatments, as listed in Table 4, in randomized complete block design. In the case of two hand weedings (HW), weeds were removed manually with a *khurpa* at 25 and 50 DAS. In Experiment 3, in interculture treatments, weeds were controlled mechanically using a tractor in case of 67.5 cm row spacing whereas in 50 cm row spacing manual weeding was done. In unweeded check plots, weeds were allowed to grow during the whole crop growing season. In case of pendimethalin treatments, the herbicide was sprayed at rates as per the treatment, on the same day or one day after sowing using knapsack sprayer fitted with flood jet nozzle using 500 litres of water ha^{-1}. In case of paraquat treatments, the herbicide was sprayed at different timings as per the treatment as directed spray between the rows using 500 litres of water ha^{-1} and using a plastic hood to avoid drift on the crop plants while spraying. Paraquat is a broad spectrum herbicide and kills all green matter. Therefore, care was taken that the herbicidal solution could not fall on pigeonpea plants. Imazethapyr was sprayed 15–20 DAS. However, in Experiment 3, imazethapyr with or without tank mix application with quizalopfop ethyl, was applied at 10–15 DAS.

2.4. Observations recorded

Dry matter of weeds was recorded 80 DAS using a quadrate measuring 50 × 50 cm^2 and at harvest on plot basis after sun-drying for about 7 days and then converted into kg ha^{-1}. Weed control efficiency (WCE) was calculated using the following formula:

$$\text{Weed control efficiency} \times 100\ (\%) = \frac{\text{Dry weight of weeds in weedy check- Dry weight of weeds in the treated plot}}{\text{Dry weight of weeds in weedy check}} \times 100$$

At maturity, data on plant height, branches $plant^{-1}$ and pods $plant^{-1}$ were recorded from randomly selected five plants from each plot, and seeds pod^{-1} from randomly selected 20 pods. Biological yield and grain yield data were recorded on whole plot basis and then converted into kg ha^{-1}. From the produce of each plot 100 seeds were taken for 100-seed weight data.

2.4. Statistical analysis

All data were subjected to analysis of variance (ANOVA) as per the standard procedure. Whenever 'F' ratio was found significant, critical difference (CD) value was calculated at p=0.05 to compare the treatment means.

3. Results and Discussion

3.1. Weeds

The predominant weed species present in the experimental site were *Commelina benghalensis* (Day flower), *Trianthema portulacastrum* (Horse purslane), *Euphorbia hirta* (Snake weed), *Digitaria* spp. (Crab grass), *Dactyloctenium aegyptiacum* (Crow foot grass) and *Cyperus rotundus* (Nut grass). Paraquat controlled all weed species whereas pendimethalin controlled all other weed species except *Commelina benghalensis* and *Cyperus rotundus.* Imazethapyr controlled sedges, grassy weeds and broadleaf weeds whereas quizalofop ethyl controlled only grassy weeds.

In Experiment 1, unweeded control recorded the highest dry matter of weeds, which was reduced drastically by all other treatments (Table 2). All the treatments of herbicides i.e. pendimethalin, paraquat and imazethapyr, applied alone

Table 2: Dry weight of weeds and weed control efficiency at harvest as influenced by different weed control treatments (Experiment 1)

Treatments	Dry weight of weeds (kg ha^{-1})	Weed control efficiency (%)
Weedy check	3152	0
T_1	329	86.2
P_1	1300	57.0
P_2	365	84.7
P_3	424	84.6
P_4	456	83.1
P_5	616	75.8
P_6	780	72.9
P_7	267	89.2
P_8	764	77.3
P_9	836	74.4
P_{10}	1026	65.9
I_1	888	67.0
I_2	828	70.8
I_3	851	70.5
Weed free	0	100.0
SEm±	320	5.2
CD (*p*=0.05)	975	15.9

T_1: Two HW(25 and 50 DAS); P_1: Pendimethalin 0.45 kg ha^{-1} (Pre-emergence); P_2: Pendimethalin 0.45 kg ha^{-1}+HW (50DAS); P_3: Pendimethalin 0.45 kg ha^{-1}+ Paraquat 0.48 kg ha^{-1} (6 WAS); P_4: Pendimethalin 0.45 kg ha^{-1}+ Paraquat 0.48 kg ha^{-1} (8 WAS); P_5: Pendimethalin 0.45 kg ha^{-1}+Paraquat 0.48 kg ha^{-1} (10 WAS); P_6: Pendimethalin 0.75 kg ha^{-1} (Pre-emergence); P_7: Pendimethalin 0.75 kg ha^{-1}+HW (50 DAS); P_8: Pendimethalin 0.75 kg ha^{-1}+Paraquat 0.48 kg ha^{-1} (6 WAS); P_9: Pendimethalin 0.75 kg ha^{-1}+Paraquat 0.48 kg ha^{-1} (8 WAS); P_{10}: Pendimethalin 0.75 kg ha^{-1}+Paraquat 0.48 kg ha^{-1} (10 WAS); I_1: Imazethapyr 75 g ai ha^{-1} at 15-20 DAS; I_2: Imazethapyr 75 g ai ha^{-1} at 15-20 DAS+Paraquat 0.48 kg ha^{-1} (6 WAS); I_3: Imazethapyr 75 g ai ha^{-1} at 15-20 DAS+Paraquat 0.48 kg ha^{-1} (8 WAS)

or in integration, significantly reduced dry weight of weeds at harvest compared to weedy check. Pendimethalin 0.75 kg ha^{-1}+HW at 50 DAS significantly reduced the dry weight of weeds which was, however, at par with all treatments except pendimethalin 0.45 kg ha^{-1}. Padmaja et al. (2013) also reported reduction in the population as well as dry weight of weeds in integration of pendimethalin with paraquat 0.48 kg ha^{-1} applied at 42 DAS. Pendimethalin @ 0.75 kg ha^{-1}+HW recorded the highest weed control efficiency due to reduction in dry weight of weeds. In pigeonpea, effective weed control has been reported with integrated use of pendimethalin and hand weeding (Rao et al., 2003; Shinde et al., 2003; Tomar et

Table 3: Effect of row spacing and weed management practices on dry weight of weeds and plants traits of pigeonpea (Experiment 2)

Treatments	Dry weight of weeds at harvest (kg ha^{-1})	Plant height (cm)	Branches plant^{-1}
Row spacing			
50 cm	1443	198.4	19.4
67.5 cm	1299	193.9	21.1
SEm±	39	2.36	0.58
CD (p=0.05)	117	NS	NS
Weed management practices			
Weedy check	3344	175.5	16.5
Pendimethalin 0.75 kg ha^{-1}	1242	194.1	21.6
Pendimethalin 0.45 kg ha^{-1}+HW 6 WAS	453	208.9	21.9
Two HW/ interculture (25+50 DAS)	445	206.2	21.1
SEm±	55	3.92	0.79
CD (*p*=0.05)	165	18.3	3.7

Table 4: Dry weight of weeds, weed control efficiency and plant characters of pigeonpea as influenced by different weed control treatments at harvest (Experiment 3)

Treatments	DWW	WCE	PH	BP
Weedy check	2911		161.9	9.4
P_1	622	78.6	190.2	15.0
P_2	856	70.6	178.7	13.1
P_3	1233	57.6	175.3	9.9
P_4	1122	61.5	170.0	10.3
P_5	867	70.2	182.1	12.6
P_6	756	74.0	186.9	13.5
P_7	956	67.2	175.2	12.4
P_8	822	71.8	186.1	13.7
P_9	1000	65.6	182.6	14.0
P_{10}	600	79.4	186.8	15.0
Weed free	0	100.0	192.8	16.3
SEm±	90		3.07	0.56
CD (*p*=0.05)	272		9.2	1.7

DWW: Dry weight of weeds (kg ha^{-1}); WCE: Weed control efficiency (%); PH: Plant height (cm); BP: Branches plant^{-1}

al., 2004; Singh et al., 2010b; Singh and Sekhon, 2013).

In Experiment 2, pigeonpea sown at row spacing of 67.5 cm recorded significantly lower dry weight of weeds than 50 cm row spacing which, might be due to more crop growth in 67.5 cm row spacing owing to more branches and resulted in more smothering effect on weeds (Table 3). Pendimethalin 0.45 kg ha^{-1}+hand weeding 6 weeks after sowing and two hand weedings/interculture recorded significantly lesser dry weight of weeds than the other treatments.

In Experiment 3, application of pre- and post-emergence herbicides in combination with hand weeding at 50 DAS recorded significantly lower dry weight of weeds than weedy check (Table 4). Two hand weedings recorded the highest weed control efficiency followed by pendimethalin 0.75 kg ha^{-1} (PE)+hand weeding (HW) at 50 DAS and tank mix application of imazethapyr 75 g ha^{-1}+quizalofop ethyl 50 g ha^{-1} (10-15 DAS)+HW at 50 DAS. Singh et al. (2010a) reported that application of imazethapyr @ 75 g ha^{-1}+Quizalofop ethyl @ 50 g ha^{-1} on 15 DAS+one hand weeding on 50 DAS/intercultivation recorded lowest dry weight of weeds.

3.2. Pigeonpea

In Experiment 1, plant height and branches plant^{-1} were recorded higher in two hand weedings and weed free than other treatments (Table 5). The pods plant^{-1} was recorded highest in weed free followed by pendimethalin 0.75 kg ha^{-1} +HW and two HW. Seeds pod^{-1} and 100-seed weight were not influenced significantly. Biological yield and grain yield of pigeonpea were significantly influenced by different weed control treatments (Table 6). Weed free treatment recorded significantly higher biological yield than all other treatments. Weed free recorded the highest grain yield, however, it was statistically at par with two HW, pendimethalin @ 0.45 kg ha^{-1}+paraquat 0.48 kg ha^{-1} (6 WAS), pendimethalin @ 0.45 kg ha^{-1}+paraquat 0.48 kg ha^{-1} (8 WAS), pendimethalin @ 0.45 kg ha^{-1}+paraquat 0.48 kg ha^{-1} (10 WAS) and pendimethalin @ 0.75 kg ha^{-1}+HW at 50 DAS. It was due to reduced weed dry matter as compared to weedy check (Table 2). Harvest index was statistically similar in all the treatments. There was no phytotoxic effect of pre- and post-emergence herbicides on pigeonpea. Padmaja et al. (2013) also reported higher grain yield with application of pendimethalin followed by paraquat at 42 DAS.

Table 5: Plant characters and yield attributes of pigeonpea as influenced by different weed control treatments (Experiment 1)

Treatments	PH	BP	PP	SP	SW
Weedy check	157.4	9.7	71.6	4.1	6.1
T_1	204.5	14.1	132.4	4.4	6.3
P_1	191.4	12.6	99.6	4.3	6.2
P_2	196.1	13.6	144.3	4.3	6.5
P_3	185.0	12.2	127.8	4.4	6.2
P_4	179.2	11.7	121.1	4.3	6.4
P_5	176.2	12.9	95.0	4.3	6.4
P_6	181.6	11.8	103.8	4.4	6.5
P_7	190.9	13.4	135.6	4.7	6.1
P_8	180.5	13.6	109.2	4.3	6.6
P_9	177.5	11.9	104.5	4.3	6.2
P_{10}	173.3	11.9	104.2	4.2	6.4
I_1	179.7	13.4	90.8	4.3	6.3
I_2	178.7	12.6	100.5	4.4	6.4
I_3	176.3	12.9	95.6	4.6	6.2
Weed free	203.3	15.6	150.1	4.9	6.6
SEm±	5.13	0.47	13.09	0.17	0.11
CD (p=0.05)	15.6	1.4	39.8	NS	NS

PP: Pods plant^{-1}; SP: Seeds pod^{-1}; SW: 100- seed weight (g)

Table 6: Biological & grain yield and harvest index of pigeonpea as influenced by different weed control treatments (Experiment 1)

Treatments	Biological yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Harvest index (%)
Weedy check	4304	750	17.6
T_1	6165	1447	23.4
P_1	5347	1276	23.2
P_2	6200	1450	24.2
P_3	5822	1454	25.9
P_4	6232	1442	24.4
P_5	5654	1191	21.3
P_6	5569	1308	24.0
P_7	5916	1466	25.7
P_8	5929	1334	25.3
P_9	6209	1310	23.7
P_{10}	6167	1223	20.6
I_1	6005	1076	18.1
I_2	6160	1177	19.7
I_3	6138	1186	19.9
Weed free	7809	1633	22.4
SEm±	497	88	2.59
CD (p=0.05)	1515	269	NS

In Experiment 2, row spacing did not influence plant height, branches plant^{-1} (Table 3), pods plant^{-1}, seeds pod^{-1}, 100-seed, biological yield, grain yield and harvest index significantly (Table 7). The plant height, branches plant^{-1} (Table 3), pods plant^{-1}, 100-seed weight and biological yield (Table 7) were higher under pendimethalin 0.45 kg ha^{-1}+hand weeding 6

Table 7: Effect of row spacing and weed management practices on yield attributes, biological yield and grain yield of pigeonpea (Experiment 2)

Treatments	Pods plant^{-1}	Seeds pod^{-1}	100-seed weight (g)	Biological yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Harvest index (%)
Row spacing						
50 cm	128.9	4.2	6.7	7702	1306	17.1
67.5 cm	130.8	4.2	6.8	7841	1343	17.3
SEm±	5.37	0.10	0.10	51	47	0.46
CD (*p*=0.05)	NS	NS	NS	NS	NS	NS
Weed management practices						
Weedy check	90.2	4.0	6.4	6345	1034	16.4
Pendimethalin 0.75 kg ha^{-1}	132.9	4.3	6.8	8000	1340	16.8
Pendimethalin 0.45 kg ha^{-1}+HW 6 WAS	147.1	4.3	6.9	8418	1452	17.4
Two HW/ interculture (25+50 DAS)	149.1	4.3	6.8	8321	1471	18.0
SEm±	6.06	0.05	0.05	227	62	0.73
CD (*p*=0.05)	28.2	NS	0.25	1060	290	NS

WAS and two hand weedings/interculture. Pendimethalin 0.45 kg ha^{-1}+hand weeding 6 WAS and two hand weedings/ interculture recorded higher grain yield than the other treatments due to more number of pods plant^{-1} (Table 7) and less competition caused by weeds (Table 3). Similar results were also reported by Singh et al. (2010a). In the case of the crop sown in 67.5 cm apart rows, mechanical interculture provided as good grain yield as with hand weeding in 50 cm apart rows (Table 8), thereby providing another option of mechanical weed control especially under labour scarcity situations.

Table 8: Interaction effect of row spacing and weed management practices on the grain yield of pigeonpea (Experiment 2)

Weed control treatment	Grain yield (kg ha^{-1})	
	Row spacings (cm)	
	50	67.5
Unweeded control	991	1076
Pendimethalin 0.75 kg ha^{-1}	1297	1384
Pendimethalin 0.45 kg ha^{-1} +HW 6 WAS	1444	1461
Two hand weedings/ Inter-culture (25 and 50 DAS)	1490	1452
SEm±	73	
CD (*p*=0.05)	NS	

In Experiment 3, plant height, branches plant^{-1} (Table 4), pods plant^{-1}, biological yield and grain yield (Table 9) were reduced significantly in weedy check than the other treatments. Weed free treatment recorded highest grain yield which was, however, at par with pendimethalin 0.75 kg ha^{-1}+HW 50 DAS. Imazethapyr 75 g ha^{-1} (10-15 DAS)+HW 50 DAS, tank mix application of imazethapyr 75 g ha^{-1}+quizalofop ethyl 50 g ha^{-1} (10-15 DAS)+HW 50 DAS, pendimethalin 0.45 kg ha^{-1}+HW 6-7 WAS and HW 25+50 DAS were the other promising treatments. Tank mix application of imazethapyr 75 g ha^{-1}+quizalofop ethyl 50 g ha^{-1} had no antagonistic effect. Post-emergence application of imazethapyr has been found

Table 9: Yield attributes and biological and grain yield of pigeonpea as influenced by different weed control treatments (Experiment 3)

Treatments	PP	SP	SW	BY	GY
Weedy check	81.3	4.0	6.27	5185	853
P_1	168.6	4.1	6.67	7284	1701
P_2	149.8	4.0	6.40	7284	1440
P_3	131.9	3.9	6.20	6543	1120
P_4	137.1	4.1	6.57	6667	1200
P_5	146.8	4.2	6.37	7284	1386
P_6	152.1	3.8	6.57	7407	1467
P_7	141.9	4.1	6.37	7037	1360
P_8	145.1	4.1	6.47	7037	1413
P_9	140.2	3.8	6.47	7654	1320
P_{10}	162.0	4.2	6.07	7778	1653
Weed free	192.9	4.1	6.47	8889	1947
SEm±	4.33	0.11	0.09	333	90
CD (*p*=0.05)	13.0	NS	NS	1000	272

PP: Pods plant^{-1}; SP: Seeds pod^{-1}; SW: 100-seed weight (g); BY: Biological yield (kg ha^{-1}); Gy: Grain yield (kg ha^{-1})

safe to soybean (Ram et al., 2013), mungbean (Singh et al., 2014a; Singh et al., 2015), blackgram (Aggarwal et al., 2014) whereas in lentil it caused phytotoxity initially but later on the crop recovered (Singh et al., 2014b).

4. Conclusion

Integrated use of (i) pre-emergence herbicide (pendimethalin) followed by post-emergence herbicide (paraquat), (ii) pre-emergence herbicide (pendimethalin) followed by hand weeding, and (iii) post-emergence herbicides (imazethapyr and imazethapyr+quizalofop ethyl) followed by hand weeding effectively control the weeds and improve the grain yield of pigeonpea. In case the pigeonpea crop sown in 67.5 cm apart rows, mechanical interculture can be done to control weeds.

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